

How are radiation and radionuclide particles measured?

There are four related - but different - units for measuring radiation:

1. **Radioactivity** (or activity), which means the amount of ionizing radiation released by a material. A substance is radioactive when spontaneously emits energy, in the form of radiation, as the result of decay due to an unstable atomic structure.
 - Whether a substance emits alpha particles (like plutonium), beta particles, gamma rays, x-rays, or neutrons, a quantity of radioactive substance is expressed in terms of its radioactivity.
 - Radioactivity represents how many atoms in the material decay in a given time period.
 - The units of measurement are the **curie** (Ci) and **becquerel** (Bq), and their subunits.
 - For Rocky Flats, data are measured in picocuries; a picocurie equals one trillionth of a curie.
2. **Exposure**, which means the amount of radiation traveling through the air.
 - The units of measurement are the **roentgen** (R) and the **coulomb/kilogram** (C/kg).
3. **Dose** (or absorbed dose), which means the amount of radiation absorbed by a person or an object. That is, the amount of radioactive energy deposited in a material or substance – like bone or organ tissue.
 - The units of measurement are the **radiation absorbed dose** (rad) and **gray** (Gy).
4. **Dose equivalent** (or effective dose), which means the combined amount of (1) radiation absorbed, plus (2) the medical effects of that type of radiation.
 - The units of measurement are the **roentgen equivalent man** (rem) and **sievert** (Sv); biological dose equivalents are commonly measured in 1/1000th of a rem (a millirem or “mrem”).

How are these units related?

A general conversion is:

1 roentgen (exposure) = 1 rad (dose) = 1 rem or 1000 mrem (dose equivalent).

Note that a measure given in Curies indicates the radioactivity of a substance, while a measure in rem gives the amount of energy deposited in a substance like living tissue, the dose. These are distinct types of measurements, and dose can depend on the type of radiation and the substance it passes through.

One cannot easily convert rem and curies and such conversions require some assumptions. To calculate the dose from a specific amount of picocuries, for example, the amount of energy deposited in a unit volume and the type of radiation emitted from the substance are needed to compare picocuries to mrem.

Different materials also have different equivalences. For example, 10 pCi/L of uranium is equivalent to an observed water concentration of approximately 14.9 µg/L (at 0.67 pCi per µg of uranium). This conversion would not be the same as for another analyte, like plutonium, which would have a different conversion factor. Specific knowledge of isotope type and health physics is required to convert.

What exactly is a picocurie?

A picocurie is a unit of measurement of radioactivity, equal to one trillionth (10^{-12}) of a curie – that's 1/1,000,000,000,000 of a curie. A picocurie represents about 0.037 disintegrations per second or 2.22 disintegrations per minute (of radioactive decay). Activity refers to the amount of ionizing radiation released by a material. Thus, the more curies - or subunit thereof - the greater the amount of radioactivity. The size or weight of a material does not indicate how much radioactivity is in it; it can vary by type of material.

So, what does that mean? Just how big is a picocurie?

A curie is quite large while a picocurie is very small. The table below shows comparisons of these amounts and puts them into context.

Unit of Radioactivity	Symbol	Disintegrations per Minute	Dollar Analogy	Examples of Radioactive Materials
1 Curie	Ci	2 trillion	About half the U.S. federal budget	Nuclear Medicine Generator
1 Millicurie	mCi	2 billion	Number of people in India, the European Union, and the United States of America, combined	Amount used for a brain or liver scan
1 Microcurie	μCi	2 million	Average price of an apartment in Manhattan, New York City	Amount used in thyroid tests
1 Nanocurie	nCi	2 thousand	Annual home energy costs	Radioactive waste
1 Picocurie	pCi	2	Cost of a hamburger	Example amount of radon in a Denver area home, below the suggested action threshold of 4 pCi/L
0.01-0.1 Picocuries	<pCi	<2	A penny to a dime	Background environmental levels of Pu on Front Range from Cold War era nuclear weapons atmospheric testing

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Resources: U.S. NRC, Measuring Radiation, available at <http://www.nrc.gov/about-nrc/radiation/health-effects/measuring-radiation.html>; U.S. Army Corps of Engineers, FUSRAP Fact Sheet (last accessed October 2016); Washington Department of Health, http://www.doh.wa.gov/portals/1/Documents/Pubs/320-059_compdose_fs.pdf; CIA World Factbook, Country Comparison – Population, <https://www.cia.gov/library/publications/the-world-factbook/rankorder/2119rank.html>; NEW YORK TIMES, JULY 1, 2015, http://www.nytimes.com/2015/07/01/nyregion/home-prices-in-manhattan-reach-new-high.html?_r=0; U.S. NRC, Waste Classification, <https://www.nrc.gov/reading-rm/doc-collections/cfr/part061/part061-0055.html>; Wright Water Engineers, Inc., *Evaluation of Water Quality Variability for Uranium and Other Selected Parameters in Walnut Creek at the Rocky Flats Site* (Sept. 2015).